Vegetative Health Assessment of Citrus Orchards using Geospatial Techniques

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Abstract

In India, citrus is grown in 1.04 million ha, covering 26 states, but only nine states contribute more than 89% of the total production. Maharashtra state in India is having the largest area under citrus cultivation in the country whereas the production is highest in Telangana followed by Andhra Pradesh and Maharashtra. The disparity between area and production of citrus in Maharashtra needs to be addressed for enhancing the productivity. One of the methods to enhance the productivity of the citrus orchards is to assess the health condition and provide the remedial measures in areas where health is poor or identity the factors for poor health. The present study carried out to assess the health of citrus orchards in Nagpur district of Maharashtra using remote sensing-based indices. Multi-temporal Landsat-8 OLI data from 2013 to 2019 and Sentinel-2 data from 2018 to 2019 were used for analysis. An area of 282 square kilometers (2.9%) was found under citrus out of 9892 square kilometers total geographical area of Nagpur district during 2018-2019. The overall vegetation health seems to be varied over the years in the study site. Citrus area under excellent health categories was found 47.4% during 2014 whereas it decreased to 2.4% and 1.5% in 2015 and 2018, respectively. About 70.1-91.9% citrus area was found under moderate health condition among seven years except in 2014 where citrus area under moderate health condition was 51.1%. The poor health conditions of citrus orchards were at par among seven years except during 2014 and 2017.

Keywords: Citrus orchards, Citrus Health, Geospatial Tech, Landsat-8 OLI, Remote Sensing Indices

Introduction

Citrus is a common term and genus of flowering plants in the family Rutaceae. The center of origin of citrus species is tropical and subtropical Southeast Asia and it is having more economic importance. Subtropical climate is best suited for citrus growth and development. Citrus plants are very sensitive to various biotic and abiotic stresses. Even through Maharashtra State in India is having the largest area under citrus cultivation in the country; the production is highest in Telangana followed by Andhra Pradesh. Maharashtra stands third in production. The disparity between area and production of citrus in Maharashtra needs to be addressed for enhancing the productivity. Citrus cultivation in Nagpur district may be plagued with various problems due to limiting growing conditions, limiting water resources and high occurrence of pests and diseases (Garik, 1990). Light irrigation with high frequency is beneficial and the quantity of water and frequency of irrigation depends on the soil texture and growth stage (Das et al., 2009). Water

requirement of citrus trees is generally higher than most of the other sub-tropical fruits due to indeterminate growth habit.

Vegetation stress is regarded as any unfavorable condition or substance that affects or blocks a plant's metabolism, growth or development. Vegetation stress can be induced by various natural and anthropogenic stress factors (Singh et al., 2003). There is growing interest among the citrus farmers to know the latest technologies for the stress condition assessment of citrus. One of the effective methods to monitor the health is assessing stress on time (Abouatallah et al., 2011). One of the most efficient monitoring methods involves the use of geospatial technology. Remote sensing plays a vital role to monitor and study the citrus crop using multitemporal satellite images. Geospatial technology is an efficient tool for monitoring and assessing citrus crops under stress as well as identifying suitable areas for its expansion. Identification of crop water stress in growing seasons is important for prediction of yield and irrigation scheduling (Payero & Irmak, 2006). Satellite remote sensing is an effective and efficient method for monitoring and analyzing citrus crops under stress. Stress assessment is essential for agricultural research to prevent the vast economic losses of cash crops (Mani & Varghese, 2018). One of the most efficient methods for stress identification is the geospatial technology, which involves the use of remote sensing technology and geographic information systems (Mani et al., 2016). Keeping this view, the present study was planned with the objective of the health condition assessment of citrus orchards in Nagpur district using vegetation health index.

Materials and Methods

Study area: The study area opted for this study is the Nagpur district, Maharashtra, India. The state of Maharashtra is leading in orange production in the country. However, more area is concentrated in Vidharbha region, mainly in Amravati, Nagpur, Yavatmal, Wardha, Washim and Buldana districts (Deshmukh, 2009). Amravati and Nagpur districts are also known as California of Maharashtra state and the city of Nagpur is proudly known as the orange city. Nagpur district has a largest area, production and productivity of oranges in Maharashtra. Nagpur district is one of the eleven districts of Vidarbha region of Maharashtra state (Figure 1). It is situated on the eastern part of the state abutting Chindwada district of Madhya Pradesh in north. It is bounded by Wardha and Amravati districts in the west, Bhandara district in the east and Chandrapur district in the south. Nagpur is a district that has its own historical importance along with its unique central location of India. It is situated along the river “Naag”, hence called as Nagpur. District lies between north latitudes 20°35’ and 21°44’ and east longitudes 78°15’ and 79°40’ with a total geographical area of about 9892 sq. km.

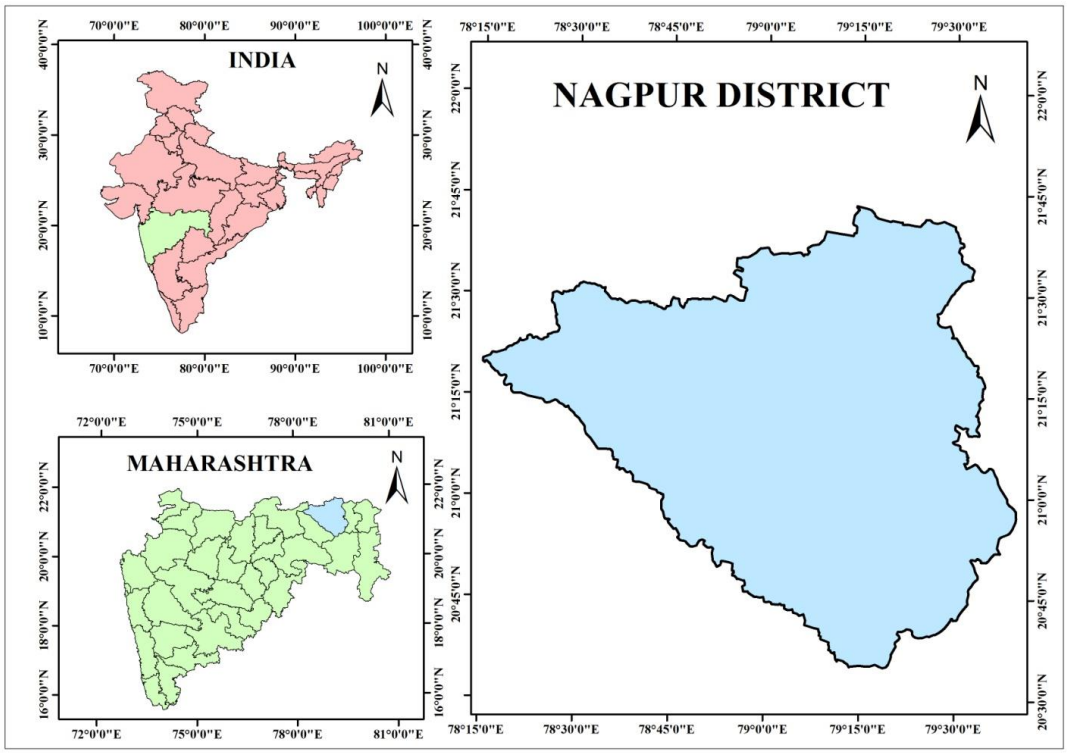

Fig. 1 Location map of Nagpur district, Maharashtra, India.

The climate of the district is hot summer and general dryness throughout the year except during the south-west monsoon season. The mean minimum temperature is about 12°C and mean maximum temperature is more than 45°C. The normal annual rainfall (1901-1992) over the district ranges from about 1000mm to 1200mm. The prominent soils occurring in the district are, black (65%), red (13%), loamy (18%) and very small percentage of sandy and red lateritic soils. Almost all soils are in the range of slightly acidic to slightly alkaline in nature. The major soil texture is clayey encompassing almost 60% of the area in the district where the clay content varies from 35 to 75%. The remaining area of the district has soil texture ranging from clay loam to sandy clay loam.

Data used: The present study is mainly focused on the health assessment of citrus orchards in Nagpur district. To estimate acreage of citrus orchards in Nagpur district, Sentinel-2 data sets were used. Data sets from this satellite were downloaded from scihub.copernicus.eu website (https://scihub.copernicus.eu/, Accessed 26 February 2021) with less than 10% cloud cover in the years of 2018 and 2019. Multi-temporal and multi-spectral data of Landsat-8 OLI were used to assess vegetative health of citrus orchards using vegetation health index of Nagpur district. These time series Landsat-8 OLI data were downloaded from USGS website (https://earthexplorer.usgs.gov/, Accessed 16 February 2021) with less than 10% cloud cover. The total study period was considered to be about 7 years i.e. from 2013 to 2019.

Methodology: The methods and techniques developed for area estimation and vegetation health assessment of citrus orchards in Nagpur district adopted for the present study is given in Figure 2.

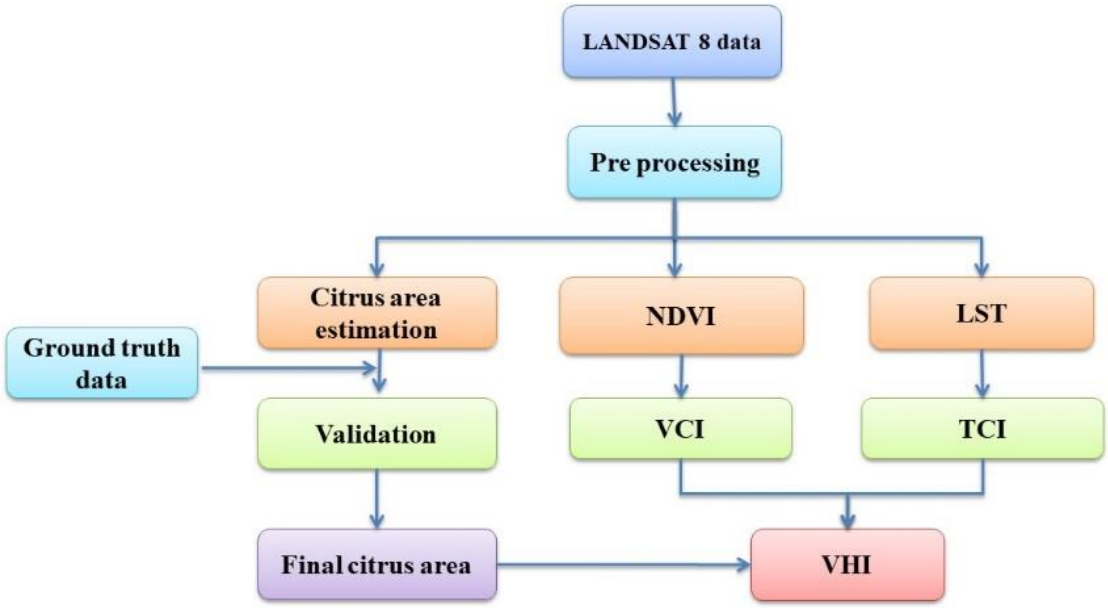

Fig. 2 Flowchart showing the steps involved in vegetation health index.

Pre-processing operations like layer stacking, mosaicking, and clipping of the satellite data were done for Sentinel-2 and Landsat-8 data. Whole Nagpur district is covered in two tiles (144-45, 144-46) of Landsat-8 data and 5 tiles (T43QHD, T44QKJ, T44QLH, T44QLJ and T44QLK) of Sentinel-2 datasets. All the layer stacked data that are covering Nagpur district area on the same date of pass were mosaicked for both the satellite data. All the Mosaicked datasets were clipped to extract Nagpur district area with the district boundary. Citrus orchards of Nagpur district are derived by visual interpretation of Landsat data.

Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI) were used to assess vegetative health and stress conditions. Land Surface Temperature (LST) was calculated using brightness temperature of two bands of TIR, mean and difference in land surface emissivity the area (Rajeshwari & Mani, 2014). The development of VHI was done using VCI and TCI indices because they are more sensitive to monitor vegetative stress than other indices (Table 1). VHI is categorized into three groups such as poor health condition (VHI 0 to 40), moderate health condition (VHI 40 to 60) and excellent health condition (VHI 60 to 100) as per Owrangi et al., 2011.

Table 1 Formulas used for the estimation of vegetation health index.

Indices	Formula*	Range
NDVI	(NIR - RED) / (NIR + RED)	-1 to +1
VCI	(NDVIi - NDVImin) *100 / (NDVImax - NDVImin)	0 to 100
LST	TB10+C1 (TB10-TB11) + C2 $(TB10-TB11)^2$ + C0 + (C3+C4W) (1-m) + (C5+C6W)Δm	Kelvin (K)
TCI	(LSTmax - LSTi) * 100 / (LSTmax - LSTmin)	0 to 100
VHI	0.5 * VCI + 0.5 * TCI	0 to 100

*NIR is near infrared region band, TB10 and TB11 are brightness temperature of band 10 and 11 respectively, W is atmospheric water-vapor content, m is mean land surface emissivity, Δm is difference of land surface emissivity and C0, C1, C2, C3, C4, C5 and C6 are split-window coefficient values (Skokovic et al., 2014).

Results and Discussions

Acreage estimation of citrus orchards: Citrus orchards were delineated in Nagpur district through visual image interpretation techniques. About an acreage of 282 square kilometers (2.9%) of citrus orchards was found in Nagpur district out of the 9892 square kilometers of the total geographical area during 2019 (Figure 3). The validation of citrus orchards delineated by visual interpretation technique was carried out using ground observations with an accuracy of about 94%.

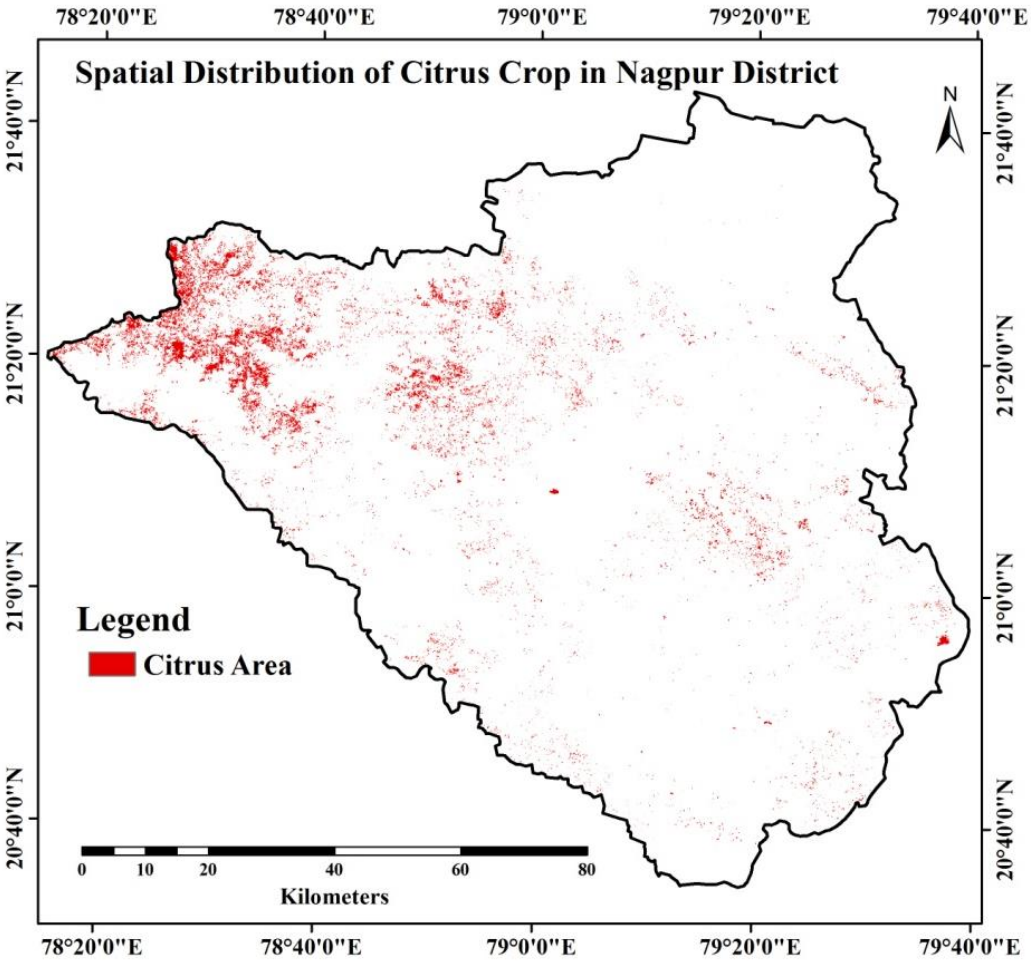

Fig 3 Spatial distribution of citrus orchards in Nagpur district during 2019.

Health assessment: Increasing human led exploitation of natural resources and climatic changes have put the biodiversity of India (which is one of the twelve mega biodiverse countries in the world) under severe threat. This has necessitated the use of appropriate technologies to formulate effective and sustainable management practices. Stress is one of the major problems to address in agricultural research due to the vast economic losses caused to cash crops because of stress. Plant stress affects crop quality and quantity therefore every possible measure must be taken to assess and address the issue of plant health in citrus crop production. Plant health assessment was carried out using integrated remote sensing and GIS techniques. The variation of abiotic stress in citrus orchards is mainly due to the difference in health status of the citrus plants. Remote sensing-based vegetation indices are able to detect the plant stress as well as health of agricultural crop.

Vegetation Condition Index (VCI): VCI determines the moisture condition of the citrus orchards based on the threshold values of NDVI. VCI is used to quantify the impact of weather on vegetation. VCI values range from 0 to 100. VCI was calculated for citrus orchards in Nagpur district over the period of 7 years (Figure 4). Lower values of VCI indicate poor health of the vegetation and higher values denotes better health of the vegetation. Nagpur district contains spatial variation of both lower and higher values in every year, but approximately most of the area is covered under medium range of VCI from 2013 to 2019. Singh et al. (2003) showed that VCI coupled with TCI should be employed as a tool to monitor both drought and excessive wetness.

Temperature Condition Index (TCI): TCI is calculated from the threshold values of LST, which is the component of temperature. TCI determines the temperature condition of the citrus orchards, higher temperature result in lower TCI value which shows low health condition and vice versa. TCI provides the reason for vegetation stress, whether stress is due to dryness or excessive wetness (Singh et al., 2003). Low values of TCI were observed in the year 2013, 2015 and 2016 for Nagpur district (Figure 5). For all the years from 2013 to 2019, Nagpur district have TCI values greater than 95. It is observed that most of the area under citrus cultivation is classified under medium range of TCI.

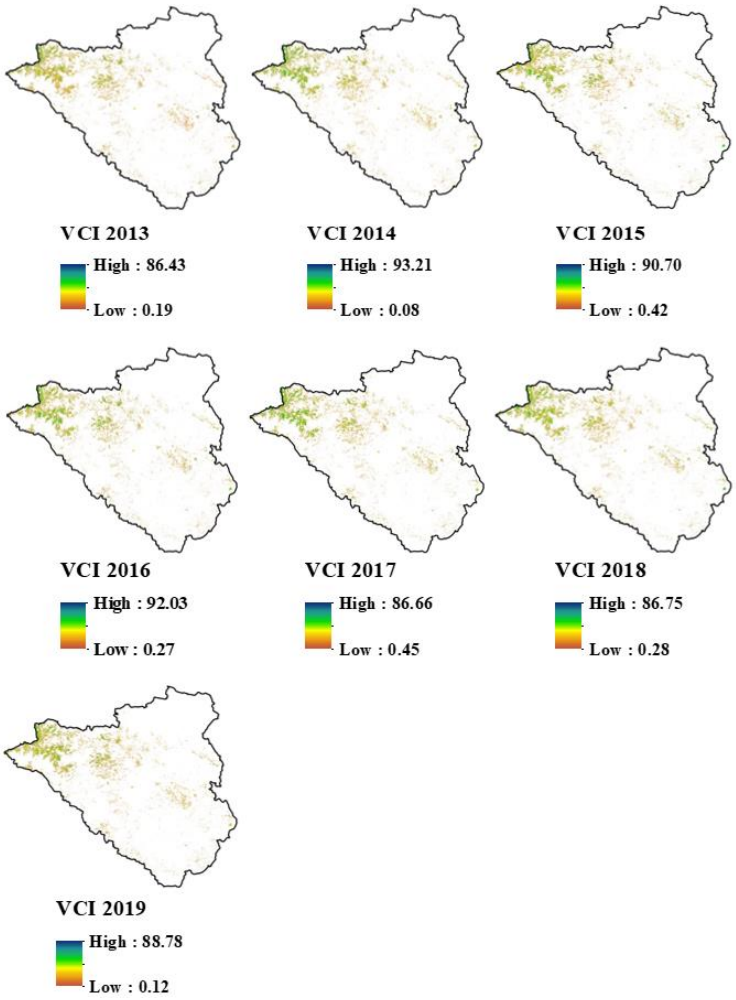

Fig. 4 Spatial distribution of VCI of citrus orchards in Nagpur district.

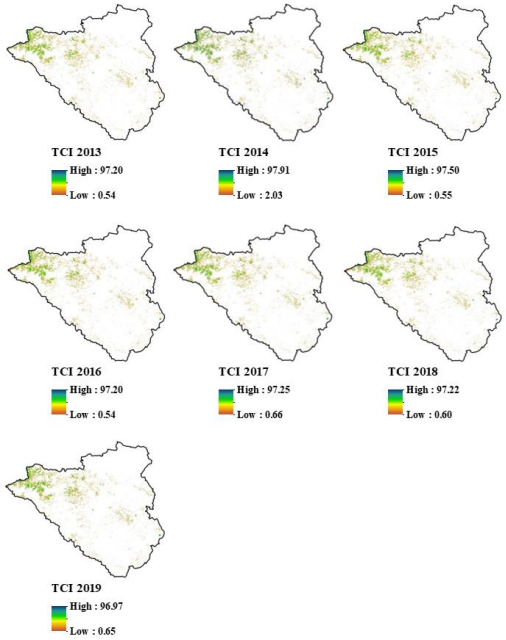

Fig 5 Spatial distribution of TCI of citrus orchards in Nagpur district.

Vegetation Health Index (VHI): VHI values derived based on TCI and VCI exhibits that VHI values of citrus orchards in Nagpur district are varying very much spatially. The citrus orchards of Kalmeshwar tehsil of the district shows good VHI values for the seven years whereas Katol tehsil also exhibit excellent health condition of citrus orchards. Most of the orchard's area were found under moderate health category (Figure 6) as per VHI and very limited percent of area was under sporadic poor health condition.

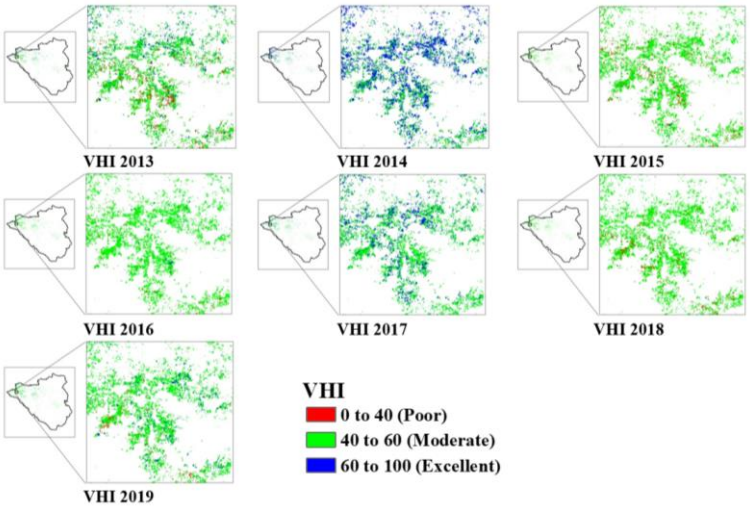

Fig. 6 Spatial distribution of VHI of citrus orchards in Nagpur district.

Citrus area under excellent health categories was found 47.4% during 2014 whereas it diminished to 2.4% and 1.5% during 2015 and 2018, respectively (Figure 7). Excellent health category of citrus was severely decreased from 2014 to 2015, but increased in 2017 about 25.1% and then diminished in the next two consecutive years. About 70.1-91.9% acreage of citrus orchards was found under moderate health condition among seven years

except in 2014 where citrus area under moderate health condition was 51.1%. The poor health conditions of citrus orchards were at par among seven years except during 2014 and 2017.

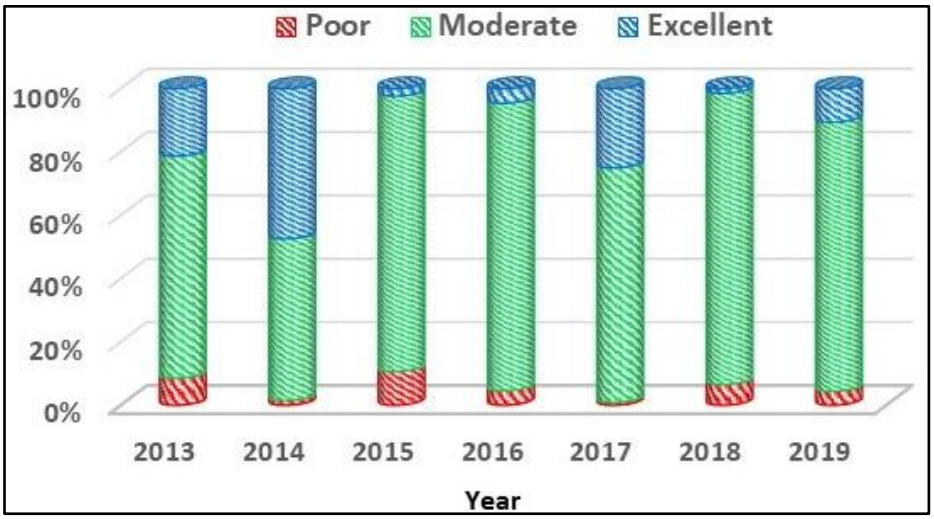

Fig. 7 Citrus area (%) under different health categories of Nagpur district.

This variation in the areas of poor, moderate and excellent health conditions of citrus orchards may be the result in the variation in the annual rainfall, that determine the moisture conditions on the crop. Similarly, Du et al. (2018) also found that VHI have a high correlation with temperature and its variability was statistically explained by changes in both precipitation and soil moisture. The citrus area under moderate health condition is likely to be in the danger and may also lead to crop water stress if proper attention was not taken.

Conclusions

Citrus farming in India is plagued with various problems like limiting growing conditions, limiting water resources and high occurrence of pests and diseases. The present study analyzed the health of citrus orchards of Nagpur district for the last seven years based on vegetation health index. An area of 282 square kilometers (2.9%) was found under citrus orchards out of 9892 square kilometers total geographical area of Nagpur district using visual interpretation of Sentinel-2 data of 2018 & 2019 years data. Vast variation in health condition is observed in citrus orchard in the study area. This variation in the areas of poor, moderate and excellent health conditions of citrus orchards may be the result in the variation in the annual rainfall, that determine the moisture conditions on the crop. About 70.1-91.9% citrus area was found under moderate health condition among seven years except in 2014 where citrus area under moderate health condition was 51.1%. in the study area. The citrus orchards of Kalmeshwar tehsil of the district shows good VHI values for the seven years whereas Katol tehsil also exhibit excellent health condition of citrus orchards. Most of the orchard's area were found under moderate health category as per VHI and very limited percent of area was under sporadic poor health condition. The present study demonstrated that remote sensing and GIS is very effective in the assessment of excellent, medium and poor health conditions of citrus orchards spatially in Nagpur district and identified areas having for management intervention.

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